

## Conference Paper

# Technical and Economical Substantiation of the Technology of Joint Pyrometallurgical Processing of Oxidized Nickel Ores and Sulfide Copper Ores

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## Abstract

The technological scheme of processing of nickel and copper ores from the Urals deposits is substantiated, including calcination of oxidized nickel ore with limestone, partial oxidative roasting of sulfide copper ore, blending of calcines with coke, and melting of charge to obtain copper-nickel matte. The implementation of the scheme will increase the complexity of possible uses of raw materials and ensure a high environmental protection level. A feasibility study was carried out for the organization of industrial enterprise, which entailed the joint processing of oxidized nickel ores and sulfide copper ores with a capacity of 700,000 tons per year of a mixture of initial ores, including 400,000 tonnes of nickel ore and 300,000 tonnes of copper ore (dry weight). Finished products are: copper-nickel matte, containing not less than, wt. %: 3.3 Cu, 4.7 Ni, 0.6 Co, 1.5 g/t Au, 2.6 g/t Ag; granular slag containing, wt. %: 0.01–0.02 Ni, 0.01–0.02 Cu, 0.01–0.06 Co, 13–16 Fe, 44–50 SiO<sub>2</sub>, 13–14 MgO, 4–5 Al<sub>2</sub>O<sub>3</sub>, 9–11 CaO; and technical grade sulfuric acid (mass fraction of monohydrate not less than 92.5 %). The planned enterprise is expected to produce the following annual volumes of finished products (not less than): 94,900 tonnes of matte; 512,300 tonnes of granular slag; and 235,500 tonnes of technical grade sulfuric acid. The estimated period of project implementation is 13 years. The total amount of investment costs is 1407 million roubles, current costs for the annual production program are 3820 million roubles. The financial results of the investment project are characterized by the following indicators: net profit is 5,735.5 million roubles, net discounted income is 1546.6 million roubles, the profitability index of discounted investments is 2.1, the internal rate of return is 36.4 %, and the discounted payback period is 5.5 years. The results indicate the viability and economic efficiency of the project.

**Keywords:** ore, processing, sulfides, oxides, copper, nickel, cobalt, smelting, extraction, products, economy, indicators, efficiency.

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Published: 31 December 2020

Publishing services provided by  
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Selection and Peer-review under the responsibility of the TECHNOGEN-2019 Conference Committee.

## 1. Introduction

The practice of metallurgical enterprises shows that the existing technologies of nickel and copper production have a number of disadvantages. In particular, the oxidized nickel

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ores (ONO) from the Urals deposits, were processed until recently by the outdated scheme, based on the reductive-and-sulfiding melting, and the matte obtained have been pyrometallurgically processed to gain high grade nickel and cobalt. Changes of non-ferrous metals market led to the closure of the Urals nickel plants and the complete cessation of processing of ONO in Russia. Sulfide copper ores (SCO) are also tough to process, their beneficiation leads to obtain copper, zinc and pyrite concentrates. Traditional methods of processing a copper and zinc concentrates allow extracting copper, zinc and a number of accessory elements into commercial products, while up to 80 % of cobalt and precious metals contained in the ore are lost with pyrite concentrates, cost-effective methods of processing of which have not yet been found. One of the ways to resume the production of nickel from an ONO and simultaneously increase the complexity of use a SCO can be the joint processing of these raw materials. Modification of reducing-and-sulfiding melting a nickel ore by using a copper ore or products of its partial oxidative roasting as a sulfidizer will allow: to exclude the formation of tailings of SCO beneficiation, to transfer nickel matte in the category of copper-nickel matte, to concentrate cobalt and precious metals in matte, to adapt the matte for processing by known routes, and to reduce the transition of sulfur into the gas phase. The results of research in the field of development a scientific bases and search for optimal modes of joint melting these ores [1–4], as well as the results of large laboratory scale and pilot scale tests confirm the prospects for industrial implementation of the technology.

The feasibility study is a necessary step in the promotion a new technical solutions. The purpose of the work is to evaluate the economic efficiency of the technology of joint pyrometallurgical processing of ONO and SCO.

## 2. Results and Discussion

The technology is based on the scheme of obtaining a copper-nickel matte (see Figure 1), the main stages of which are: ore preparation, oxidative roasting (850 °C) of SCO in a fluidized bed furnace, calcination (800 °C) of ONO with the addition of flux (limestone) in a tubular rotary furnace, and reducing melting (1300 °C) of a mixture of calcines in an electric furnace. The initial raw materials were SCO from Dergamyshskoye deposit and ONO from Serovskoye deposit (see Table 1).

Based on the experimental data and the experience of existing production facilities, the following modes and characteristics were taken for metallurgical calculations: the weight ratio of ONO: SCO: limestone: coke = 100: 75: 20: 5 (on dry basis); moisture of the ONO and SCO – 30 and 5 % respectively; the masse losses after pretreatment and roasting – 0.8 %; extraction level from the charge in matte after melting, %: 95 Cu, 97 Ni,

85 Co, 99.5 Au, and 99.5 Ag; throughout extraction level in matte from the initial ores, %: 94.2 Cu, 96.2 Ni, 84.6 Co, 98.7 Au, and 98.7 Ag; the desulfurization degree during roasting and melting – 73 and 13.9 % respectively; throughout extraction level of sulfur from the ores in sulfuric acid – 75.5 %.

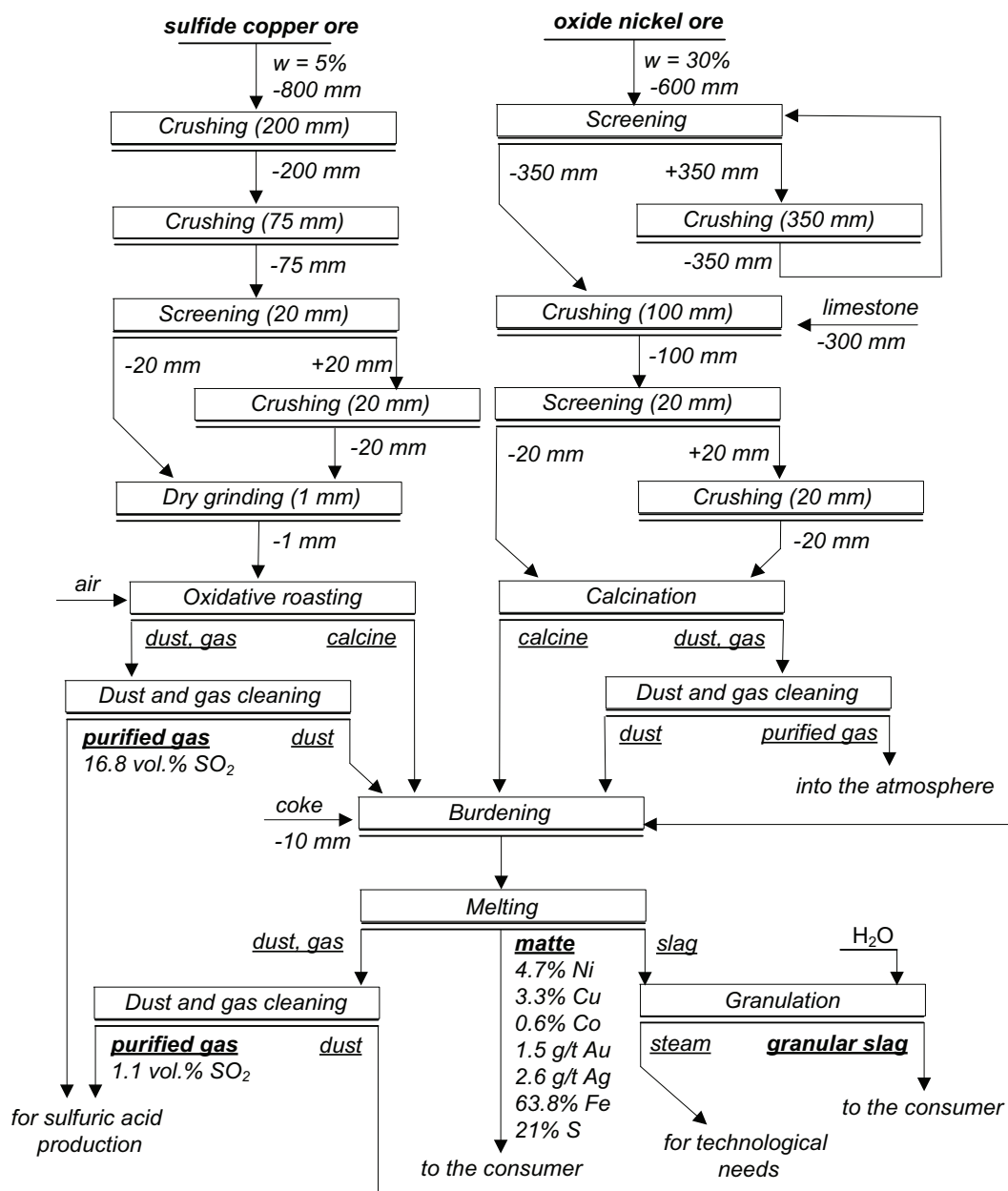


Figure 1: Technological scheme of the ores processing. (Author's own work).

TABLE 1: Chemical composition of the ores. (Author's own work).

Ore type	Content, wt.%									
	Ni	Cu	Zn	Fe	S	Co	SiO <sub>2</sub>	MgO	Al <sub>2</sub> O <sub>3</sub>	CaO
SCO	0.01	1.0	0.8	33.6	27.7	0.12	17.0	7.4	2.3	1.2
ONO	1.20	<0.01	<0.01	8.1	0.2	0.06	52.6	13.6	10.2	1.0

The production capacity of the ore mixture (dry weight) is 700,000 tonnes per year, including 400,000 tonnes of ONO and 300,000 tonnes of SCO. As part of the enterprise it is planned to organize 3 departments: ore preparation department, melting department, and sulfuric acid workshop. The finished products are: copper-nickel matte, containing not less than, wt.%, 3.3 Cu, 4.7 Ni, 0.6 Co, 1.5 g/t Au, 2.6 g/t Ag; granular slag, containing, wt.%, 0.01–0.02 Ni, 0.01–0.02 Cu, 0.01–0.06 Co, 13–16 Fe, 44–50 SiO<sub>2</sub>, 13–14 MgO, 4–5 Al<sub>2</sub>O<sub>3</sub>, and 9–11 CaO; technical grade sulfuric acid (mass fraction of monohydrate not less than 92.5 %). The planned enterprise is expected to produce the following annual volumes of finished products: not less than 94,900 tonnes of matte; not less than 512,300 tonnes of granular slag; and not less than 235,500 tonnes of technical grade sulfuric acid. The ONO calcination waste gases and the sulfuric acid production waste gases will be waste materials; after cleaning to the level of maximum permissible concentrations of pollutants in the atmospheric air they will be emitted into the atmosphere. In case of the enterprise would be placed on the industrial site of one of the Urals conserved nickel plants, investment costs in the project will amount to 1.4 billion roubles (see Table 2).

TABLE 2: Investment costs. (Author's own work).

Items	Costs, million roubles
1. Predesign works	7.5
2. Design	30.0
3. Purchase of equipment	813.1
4. Construction and installation works	406.5
5. Current assets	150.0
Total	1407.1

The total costs of annual output will be 3.8 billion roubles (see Table 3). Labor costs are estimated on the basis of the list number of employees in the enterprise, for continuous operation of 350 people, including: basic and auxiliary workers – 214 and 122, respectively, managers and specialists – 14, respectively.

The price of copper-nickel matte (38,300 roubles per tonne) adopted based on the assessment of the target components contained in the product using reduction factors to their price on the London Metal Exchange at the date of settlement. Other commercial products of the enterprise are estimated according to their market value: granulated slag – 200 roubles per tonne; technical sulfuric acid – 2500 roubles per tonne (see Table 4).

The financial results of the implementation of the proposed technology are calculated in accordance with the current legislation of the Russian Federation and take into account income taxes (20 % rate) and property taxes (2.2 % rate). The assessment of the

project's viability was carried out according to standard methods based on the following conditions: investment life – 13 years (the first 2 years – design works, construction works and development of production; the next 11 years – operation of the enterprise at the design capacity); discount rate – 12 %; financing of initial capital investments is carried out through a bank loan with a real interest rate equal to the refinancing rate of the Central Bank of the Russian Federation (9.25 %); the need for investment in the operational phase of enterprise is covered by the generated net profit and planned depreciation. The following indicators are calculated as the determining criteria of the project effectiveness: net profit, net discounted income, profitability index of discounted investments, internal rate of return and discounted payback period (see Table 5).

TABLE 3: Current costs of the annual production program. (Author's own work).

Items	Costs	
	million roubles	%
1. Cost of materials	3059.0	81.7
2. Cost of remuneration of the main workers	89.9	2.4
3. Social contribution	27.0	0.7
4. Overhead (without out-of-production)	351.0	9.2
5. Cost of sales	35.1	0.9
Total operating costs	3561.9	93.2
6. Financial costs	142.0	3.7
7. Depreciation	116.1	3.0
Total costs of the entire issue	3820.0	100

TABLE 4: Project performance indicators. (Author's own work).

Parameter	Copper	Nickel	Cobalt	Gold	Silver
Contents in matte, wt. %	3.3	4.7	0.6	1.5 g/t	2.6 g/t
Metal weight in matte, tonne per tonne of matte	0.033	0.047	0.006	1.5 g	2.6 g
The price of fine metal, per tonne*: USD	5939	10,900	59,000	40.4	0.5
thousand roubles**	352.7	647.4	3504.0	2.4	0.03
Reduction factor	0.55	0.55	0.55	0.85	0.80
Cost, thousand roubles per tonne of matte	6.4	16.8	11.9	3.1	0.07

\* – for gold and silver – per 1 gram;

\*\* – at the rate of 59.39 roubles per USD.

### 3. Conclusions

Analysis of the performance indicators of the project of joint processing of ONO and SCO allows us to draw the following conclusions. Net discounted income for the period of consideration (1546.6 million roubles) has a positive value, and the value of the profitability

TABLE 5: Project performance indicators. (Author's own work).

Indicators	Value
Net profit, million roubles	5735.5
Net present value, million roubles	1546.6
Internal rate of return, %	36.4
The index of profitability of discounted investments	2.1
Discounted payback period, years	5.5

index of discounted investments (2.1) is much more than 1, so the project should be recognized as appropriate. Internal rate of return (36.4 %) is significantly higher than discount rate (12.0 %), and discounted payback period (5.5 years) is acceptable in the metallurgical industry; these facts confirm the profitability and attractiveness of investments. The results indicate the viability and economic efficiency of the developed technology. An important advantage of the planned production are technical solutions to reduce environmental damage from its activities through the rational distribution of sulfur between products (matte and sulfuric acid) and disposal of waste slag in the construction industry.

## Funding

The work was carried out according to the state assignment for IMET UB RAS.

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